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BUREAU OF PLANT INDUSTRY—BULLETIN NO. 145.
B. T. GALLOWAY, *Chief of Bureau.*

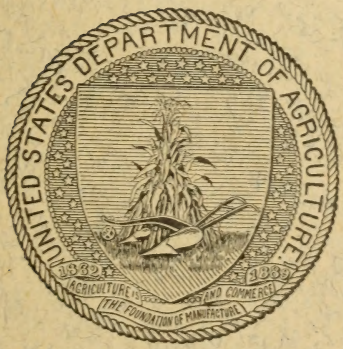
VEGETATION AFFECTED BY AGRICULTURE IN CENTRAL AMERICA.

BY

O. F. COOK,

BIONOMIST, BUREAU OF PLANT INDUSTRY.

ISSUED APRIL 10, 1909.



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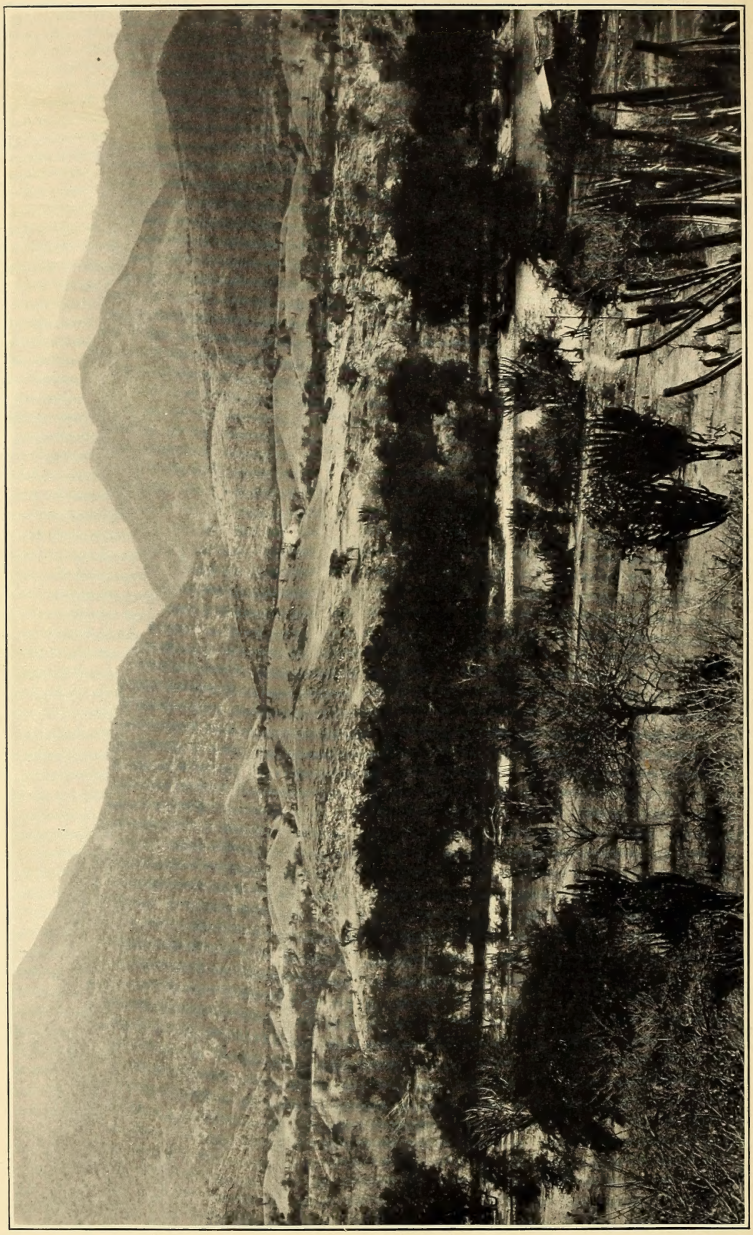

DENUDED LANDS OCCUPIED BY CACTUS DESERTS, NEAR EL RANCHO, EASTERN GUATEMALA.

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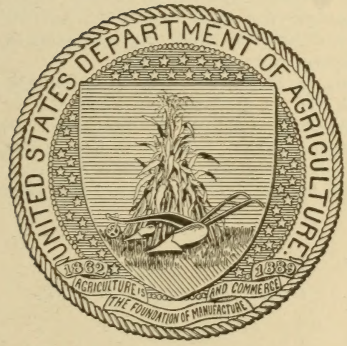

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U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., January 29, 1909.

Sir: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 145 of the series of this Bureau, a manuscript entitled "Vegetation Affected by Agriculture in Central America," by Mr. O. F. Cook.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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VEGETATION AFFECTED BY AGRICULTURE IN CENTRAL AMERICA.

INTRODUCTION.

That climate and other natural conditions of existence have had their influences upon the development of civilization in different parts of the world has often been recognized, but relatively little study has been given to the corresponding influence of man on his environment. The two questions are in many ways inseparable, for we can hardly gain a correct idea of one without taking the other into account.

Savages who live by hunting and fishing or upon wild fruits, seeds, and honey may occupy a tropical region without seriously disturbing the previous balances of organic nature; but no careful observer of the agricultural aborigines of the Central American countries can doubt that they have had very definite influences upon their surroundings, or that influences of the same kind have been exerted for long periods of time.

Humboldt and other geographical writers have reported the existence of very diverse types of vegetation in different parts of Central America, and have proposed various geological and meteorological explanations of the distribution of the different kinds of plant life, the dense tropical forests, scattered growths of pine and oak, open grass lands, and cactus deserts. (Pl. I.)

As a matter of fact, these varied types of vegetation are not restricted to particular altitudes or to particular geological formations. There are open fire-swept grass lands near sea level and at many different elevations, and even on the upper slopes of the highest volcanic peaks. Similar wide ranges of altitudes and conditions are shared by the pines, oaks, and other trees which represent various stages of a general process of reforestation. Cacti thrive in barren places near the coast and also on the high interior plateaus.

That the geological and meteorological influences are often very important need not be denied, but their effects can be correctly estimated only when the other factors of the problem are considered, not by taking it for granted that the present conditions represent, or even approximate, the primeval state of the country. Unless

we can form a definite idea of the original conditions we can not expect to judge of their influence on primitive man, nor can we determine what effects man has had upon the vegetation and other natural conditions. We need what might be called a bionomic base line, an idea of the conditions which existed before man came upon the scene, the conditions which would again supervene if the human inhabitants were withdrawn.

To invoke other than the human agencies to account for the present lack of forests in many parts of Central America is superfluous, for the destructive abilities of the Indians are everywhere in evidence. Reforestation is everywhere going on, but the Indians are also busy cutting down and burning the woody vegetation. If the burning over of the land were limited to areas ready for planting the general results would be far less disastrous, but the fires are usually allowed to spread wherever there is fuel to carry them, and large tracts of land are thus kept in a permanently barren condition. At night in the farm-clearing season the burning mountain slopes gleam with lines of light like the streets of distant cities. By day the sky is darkened and the air is heavy with smoke. That regions now so barren as the valley of Salama in central Guatemala may be artificial deserts cleared by human agency can readily be understood when the facts are viewed at first hand. The devastation which can be worked in a single corn-planting season will go far to convince the careful observer that the native methods of agriculture have wide-reaching effects.

The Central American Indians are extremely conservative people. Even those who have learned to speak Spanish and to wear European clothes still continue to follow their own primitive systems of agriculture without any appreciable change. With the exception of a limited use of wheat and of broad beans at very high elevations, no European field crops have been adopted by the Indians, much less any European methods of cultivation. Thus the present conditions may be relied upon as giving us a correct idea of the agricultural influences which have long been at work in these countries.

DIVERSE SYSTEMS OF MAIZE CULTURE.

The problem of tracing relations between agriculture and natural conditions in Central America is much simplified by the fact that one staple crop is grown over the whole area, including the humid tropical lowlands, the dry interior table-lands, and the cold, cloud-covered mountain slopes of high elevation. In spite of endless local diversities among the native inhabitants they have a general agricultural unity, for they all depend on Indian corn, sometimes to the almost complete exclusion of other kinds of food.

No one variety or type of corn thrives under so wide a range of natural conditions, but the Indians have many highly specialized varieties and many specialized methods of cultivation. These have made it possible for Indians to occupy and deforest any part of the Central American region. The large numbers and varied characters of these specializations of varieties and of cultural methods afford important evidence of the very great antiquity of the primitive agricultural civilizations in Central America.[a]

The mountainous contours of this region, together with the lack of large navigable rivers and of beasts of burden, have tended to prevent the development of great centers of civilization like those of ancient Egypt and Assyria. Neither were there any wide areas of alluvial lands adapted to permanent cultivation by the Indian methods of agriculture. The dry plateaus were the scenes of the Aztec and Inca civilizations which happened to be flourishing at the time of the Spanish conquest, but widely scattered ancient remains show that many other primitive cultures had developed and disappeared in earlier times, even in the humid lowlands.

The want of means of transportation to bring food from longer distances limited the size of native communities and prevented the simultaneous devastation of large regions, as in the Old World. A barren zone surrounding each town is a regular feature in Central America, leaving no doubt of what the results would have been if such communities could have grown to large size. (See Pl. II.) Supplies of firewood and of building timbers for Salama, Cobán, and other large towns in the interior of Guatemala are regularly carried in on the backs of Indians for two or three leagues, and often for greater distances. Indians from San Pedro Carchá, near Cobán, often plant corn over fifty miles away, in the Cahabón district, and carry the crop home on their backs.

The lack of draft animals prevented the development of the art of plowing, which might have enabled more use to be made of the land but would also have brought about a more complete and lasting denudation. The usual custom of natives of tropical countries to raise only one or two crops in each clearing appears very wasteful, but it has the advantage of making only small drafts on the fertility of the soil. The humus layer is not destroyed by fire, and the roots remain in the ground to resist erosion. Much of the vegetation survives the cutting and is ready to begin at once the process of reforestation. The corn may even be planted before the burning takes place if the rains continue too long or begin too early.

[a] Indications of corresponding specializations in cotton culture have been noted in other papers: An Enemy of the Boll Weevil, Report 78, U. S. Dept. of Agriculture, and Cotton Culture in Guatemala, Yearbook, U. S. Dept. of Agriculture for 1904, pp. 475–488.

In a semiarid district of northwestern Guatemala the natives do not find it necessary to cut down the vegetation before burning, but simply set it on fire at the end of the dry season. The corn is planted immediately afterwards. The first light rains wet the loose surface soil and the young corn shoots up before the other plants begin to recover from the injuries of the fire. This method of burning the forest without cutting is the simplest system of corn culture thus far recorded. The alternative of cutting the forest down without burning is reported by Prof. H. Pittier as occurring in very humid districts on the west coast of Colombia, where the felled trees do not become dry enough to burn.

In many localities the crop receives no further care than the cutting, burning, planting, and harvesting. In some places it is customary to pull out the weeds; in others the weeds are not only pulled but the earth is hoed up around the stalks, as in the United States. Sometimes this is carried almost to the extent of plowing the land, for the hills are made very large. The seed is planted on little mounds of earth hoed from the sides of old hills, which are afterwards demolished and rebuilt around the young plants.

The most specialized form of corn culture is found on the higher slopes and summits of the mountains. The corn is planted every other year on narrow step-like terraces only a few feet wide. The weeds that grow up in the fallow year serve as green manure. They are chopped and covered in by hoeing down a part of the terrace next above. (See Pl. III.) The contours of many of the mountains in central Guatemala in the region of Cobulco and Quiché appear to have been smoothed down and made regular by this laborious system, which has probably been handed down from remote times. Where the rains are gentle and the soil is renewed by a friable, gradually disintegrating subsoil, this affords a practically permanent system of agriculture. There is no reforestation, but at the same time there is no destructive erosion, and the fertility of the soil is maintained by the incorporation of a regular supply of vegetable matter. European settlers have also applied it to wheat, which is raised in considerable quantities in the region of Totonicapam and Quezaltenango, where the photograph shown as Plate III was secured.

The only other method of corn culture that approaches permanence is that carried on in small gardens or yards in Indian towns. San Pedro Carchá, near Cobán, affords a notable example of a populous community living, as it were, in one continuous, permanent cornfield. The soil is deep and shows no signs of exhaustion, though it has borne annual crops of corn ever since the Spaniards explored the country, and probably for many centuries before. Thus some of the native towns in their limited areas remain quite productive

spots, though their inhabitants may have reduced the surrounding country to a desert.

OCCUPATION OF CLEARED LANDS BY GRASSES.

The usual system of corn culture involves the repeated burning off of the woody growth and a resulting exposure of the soil. This causes a gradual deterioration of the crops of corn and a slower renewal of the woody vegetation. New clearings in the forest are soon covered again with bushes, and can be cut, burned, and planted again within a year or two. With each cutting the interval has to be lengthened, until finally the land becomes thoroughly occupied by coarse grasses which are not killed by fire. The Indians can then make no further use of the land for agricultural purposes.

Fires set to burn the brush off clearings are allowed to spread over the adjacent tracts of abandoned land. These accidental burnings give the grass an advantage over the woody vegetation, and the grassy areas are gradually extended. The Indians know well enough that the frequent burning over of the old cornfields keeps the land from being used again, but their interest in the future is seldom strong enough to lead to any precautions against the spreading of the fires.

Reasons have been given in another place for believing that the prairies of south Texas were kept in a treeless condition by fires in the same way as the grass-land districts of Mexico and Central America. In Texas the woody vegetation has been able to make rapid advances in recent decades because the grass is grazed and the stockmen burn the residue off every year, thus putting an end to destructive fires.[a] That frequent fires aid reforestation has also been observed by Professor Pittier on savannas in the southern part of Costa Rica, near the Pacific coast. The Indians did not make a practice of burning the savannas, which were thus left for accidental fires at long intervals, but the fires kindled every year by the civilized settlers are not severe enough to kill the bushes and trees, and the woody vegetation is now making rapid advances.

EXTINCTION OF GRASSES BY FOREST.

Under normal conditions of Indian agriculture, where burning is left to chance, the occupation of the land by the grasses is likely to continue as long as the proximity of agricultural natives insures the access of fires at the necessary intervals. If a place is abandoned and no fires are set for a sufficient period of years the grass is invaded by woody vegetation and is finally overshadowed and killed.

[a] Cook, O. F. Change of Vegetation on the South Texas Prairies. Circular 14, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1908.

In some localities it is evident that the woody vegetation may make a slow and gradual conquest, even in spite of occasional fires, if sufficient time is allowed and no new clearings are made. Many localities which are now open grass country or are covered with scattering pines, oaks, or Curatella trees are being reforested by dense tropical vegetation, wherever the opportunity is afforded by a cessation of cutting and burning. (See Pls. IV, V, and VI.)

Where the grasses are suitable for cattle and are eaten and trampled by grazing animals the fires are rendered less severe and less frequent, and there is more rapid progress toward reforestation. In districts where sheep are grazed, as in the highlands of the Department of Quiché, Guatemala, the grass is kept too short to protect the land, and a very destructive erosion can then take place. Surfaces which retained their gently sloping contours under the native system of agriculture are now becoming thickly gashed with gullies and ravines whose steep, crumbling slopes remain naked of all vegetation. The complete devastation of such areas seems likely to ensue unless the sheep are withdrawn.

BOTANICAL INDICATIONS THAT MANY FORESTS ARE OF RECENT GROWTH.

Reforestation can be traced through a succession of temporary types of vegetation, such as pines, oaks, Curatella, Acrocomia, Cecropia, Castilla, and Attalea. These are abundant in regions undergoing reforestation, but are extremely rare in virgin forests or in those sufficiently old for the tropical hard-wood trees to have grown to maturity and occupied the land, along with their attendant hosts of epiphytes and shade-tolerant undergrowth. It thus becomes evident that many of the existing forests are not permanent or primeval, but show the intermediate stages of a process of reforestation which probably requires several centuries to reach a stable condition.

While this permanent forest covering is becoming established the temporary and intermediate types are gradually crowded out and may be almost completely exterminated in districts where the forests have remained undisturbed for sufficiently long periods of time. Thus the absence of rubber trees (Castilla) and of Attalea palms from the forests along the Rio Dulce region of eastern Guatemala may be taken as evidence that this district has not been occupied by Indians for many centuries.

Such facts have to be taken into account in estimating the agricultural possibilities of a locality. Scarcity of wild rubber trees does not prove, for instance, that a place is unsuited to rubber planting, but may mean merely that there has been no agricultural occu-

pation of that part of the country in recent times.[a] Attalea palms are described as very abundant about the ruins of Copán, in Honduras, which means that the present occupation of the country has continued for a long time. The scarcity of these palms and of wild rubber trees in the neighborhood of the extensive ruins of Palenque, in southern Mexico, would show that this region has not been occupied by Indians in recent centuries. History confirms this indication. The great Cortez himself passed close to Palenque on his way to Honduras. Though searching for Indian cities, he found only uninhabited forests and appears not to have learned that the ruins existed.

PREVIOUS DENUDATION SHOWN BY ABSENCE OF UNDERGROWTH PALMS.

Central America is the home of many species of Chamaedorea and other small palms which live among the undergrowth in the shady depths of the forests. Nevertheless, many localities affording conditions apparently suitable for these palms are without any representatives of the group. The undergrowth palms remain abundant only in regions which have not been completely deforested for agricultural purposes, and especially in districts too mountainous and broken for agricultural use.

Though palms are generally able to grow under a rather wide range of conditions, they can spread only slowly, for their seeds are large and appear to have no ready means of transportation except the wood pigeons, which are exterminated with the forests. Further evidence that the palms spread very slowly is to be found in the fact that nearly all of the native species appear to be quite narrowly localized. The Costa Rican species are not known from Guatemala, nor the Guatemalan species from Mexico, except along the border.

PREVIOUS DENUDATION SHOWN BY ABSENCE OF HUMUS-INHABITING ARTHROPODS.

Localities which contain remnants of ancient forests can be recognized by the presence of complete faunas of humus-inhabiting forest animals, such as the millipeds and centipeds, and some of the lower orders of insects and arachnids. In districts which are frequently cleared by cutting and burning many of the humus-inhabiting groups are exterminated. Even if they escape the fire they are unable to resist the exposure to the heat, sunlight, and dryness of cultivated lands. As long as the surface soil retains its humus and remains loose and pervious to water some of the smaller subterranean forms

[a] Cook, O. F. Culture of the Central American Rubber Tree. Bulletin 49, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1903.

will persist, but when denudation is complete or when the soil becomes sticky and impervious the humus-inhabiting types entirely disappear, as in many of the tenacious "gumbo" soils of the Texas prairies.

Many forested places in Central America which now afford conditions favorable for these humus-loving animals are occupied by small and incomplete faunas. This shows that the period of reforestation has not been long enough to permit these sedentary, slow-moving creatures to spread again over the reforested areas. Thus, in the valley of Ocosingo in southern Mexico are many such tracts of new forest in which the humus fauna is still very poorly represented. Nevertheless, the woody growth which now crowns the extensive ruins of Tanina, a few miles from Ocosingo, shelters a rich fauna of humus-inhabiting types. It seems impossible to account for the presence of such a fauna except by supposing that there was a complete and long-continued reforestation of the district after the ruins were built, but before the present population came in and cleared the land anew.

Of the periods of time required for such changes to be accomplished only rude estimates are possible in the present state of our knowledge. A thousand years appears a small allowance for the complete reforestation of a thoroughly denuded region and for the spread of the humus-inhabiting organisms over the reforested country. The survival of the humus-inhabiting animals on the ruin-covered hill is hardly to be considered possible, for the pyramids and chambered buildings which covered the summit, as well as large areas of the elaborately terraced approaches, appear to have been faced all over with cement.

Populous Indian communities, such as the builders of these ruins must have formed, not only cut down all the accessible forests to plant corn, but keep the surrounding country stripped of woody growth to supply the never-ceasing demand for fuel. Long after all the lands for many miles around are exhausted the community may persist, so great is the disinclination of the Indian to leave the place where his forefathers have lived. Thus the abandonment and reforestation of a district has always to be thought of as a slow and gradual process, requiring much more time than would be needed if the vegetation could be left entirely alone. In like manner it must be considered that a long period is required for the reoccupation and development of a new native culture in a district in which the forest growth has been allowed to become fully restored.

Of the sudden movements of large bodies of population as results of wars and conquests there are no indications in the habits and traditions of the peaceable, sedentary agricultural natives of this region. Each successive occupation is to be thought of as slowly growing

into a new region and as slowly dying out as the agricultural possibilities of the land became exhausted. Thus, if no time were lost in the reoccupation of a region like that of Ocosingo as soon as reforestation had become complete and the humus-inhabiting organisms had regained their natural distribution, the intervals between successive occupations are not likely to be less than two or three thousand years, and might easily be greater.

DESERT VEGETATION IN DENUDED AREAS.

The Cahabón district of eastern Guatemala affords an excellent example of an artificially cleared area surrounded by larger tracts of forested country. The greater length of the dry season in Cahabón is a fact familiarly recognized by residents and proved by the presence of cocoanut palms and other types of vegetation which do not thrive in continuously humid regions away from the seacoast. The traveler who visits Cahabón in the spring months may have even more vivid evidence, for he may see day after day showers of rain falling a few miles away before any come to Cahabón.

The contrast with the neighboring forested districts is strengthened, no doubt, by the somewhat lower elevation and higher temperature of the Cahabón region. Yet forests would soon cover the whole district if agriculture ceased, and would certainly affect the factors of temperature and humidity by which the rainfall is controlled.

A similar instance is found on the eastern slope of Costa Rica. If the testimony of intelligent men who settled in this region a quarter of a century ago is to be believed, the rainfall was then distributed through the entire year, as it still is in adjacent districts where the forests remain. But in the narrow belt of cleared lands along the railroad that climbs the slope, the dry seasons have become longer and longer. In recent years destructive droughts have occurred and severe windstorms, also quite unknown before the forests were cut away.

That many localities in the Old World which once were occupied by populous civilizations are now abandoned deserts has long been known to historians and archæologists. Some writers have held that such changes could only be explained by supposing that denudation has changed the climate and caused a general reduction of the rainfall. The facts observed in Central America show that denudation may bring about artificial desert conditions, even where the total rainfall continues to be sufficient for the growth of forests. It is only necessary that the vegetation be cleared away and that the dry season be lengthened.

The exclusion of the more delicate moisture-loving types of plant and animal life from denuded regions is sufficiently explained by the

greater dryness of the atmosphere and the lengthening of the dry season, conditions which are evidently intensified by the exposure of the earth to the sun. Denudation allows the rain water to run off at once, and thus reduces the amount of moisture available for evaporation into the atmosphere. At the same time the relative humidity of the air is decreased through the greater radiation of heat from the exposed, sun-baked earth. The earlier and later rains are diminished and the dry season is lengthened until only the drought-resistant types of vegetation are able to survive. Even if there were no change at all in the amount of rainfall, changes in the distribution of the rainfall would have serious effects on the vegetation.

On large continental land masses where there is an extensive circulation of the atmosphere exposures of the bare earth may appear to have no very definite effect upon the climate, but in Central America the effects of local conditions are often readily appreciable. The regular alternation of land and sea breezes within a few hours does not compel any general circulation of the atmosphere, but only slight local displacements. Precipitation follows relatively small fluctuations of temperature and is the more readily and obviously influenced by local conditions. A column of heated air rising from a denuded district can often be seen to absorb the clouds which drift over from a neighboring forested area. A striking example of this phenomenon [a] can be seen in the spring months from the crest of the mountain which overlooks the valley of Salama, on the road to Rabinal. (See Pl. VII.)

PREVIOUS OCCUPATIONS SHOWN BY ARCHÆOLOGICAL REMAINS.

Many localities which are now occupied by apparently virgin forests are shown by archæological remains to be regions of reforestation. Thus in the Senahu-Cahabón district of Alta Vera Paz relics of two or three very different types of primitive civilizations indicate that as many ancient populations have occupied successively the same areas which are now being cleared anew by the coffee planters as though for the first time.

It does not yet appear that any considerable region of forest has been explored in Central America without finding similar evidence that the present forests are not truly virgin growth. Even in extremely humid and insalubrious lowlands of the Atlantic slope of Costa Rica many relics of ancient civilizations have been uncovered in clearing away the heavy tropical forests to make banana planta-

[a] A similar effect is reported by Darwin from Brazil (see Voyage of the *Beagle*, Chap. II), but is described as occurring near sunset, whereas it may be seen in Guatemala during several hours of the day. The clouds are not collected about elevated summits, but float higher in the air.

tions. The same has recently been found to be true of the uninhabited coast regions of eastern Guatemala.

It is not probable that more than a small proportion of the native tribes which have inhabited the Central American region were builders of stone structures or other permanent monuments by which ancient occupations could be proved. The likelihood that many tribes might pass without leaving any permanent evidence of their existence makes it the more remarkable that all parts of Central America have in one prehistoric age or another been the scenes of primitive agricultural civilizations sufficiently advanced to work in stone, or at least to pile up terraces or earthworks of regular form. Some of the more barbarous tribes might occupy a region for thousands of years and yet leave no traces other than the fragments of broken pottery. These fragments are so abundant and so generally distributed in Central America that they appear as a regular constituent of alluvial soils and surface deposits.

But even the pottery may not mark the limits of primitive civilization, for the Central American pottery is not glazed, and after a sufficient lapse of time it crumbles away. A more striking evidence of antiquity could scarcely be imagined than the gradual crumbling down of large earthenware pots left by prehistoric man in dry caves of eastern Guatemala. Of the skeletons beside the pots only the teeth remain, and of the pots themselves only the rims or little circular mounds of earth. We can not know how long it has taken the pottery to crumble, but we can at least contrast the condition of these decayed pots with other pieces of pottery placed in caves of the same district in later prehistoric ages, which still appear fresh and new, as though recently burned. And yet the bones beside these apparently new pots have also crumbled nearly to dust, and there has been time for the surrounding country to be occupied with old forests of hard-wood trees, like true virgin growth.

PREHISTORIC AGRICULTURE SHOWN BY TERRACING OF LAND.

Terracing of the land shows that agriculture was extensively practiced in former times in regions now unoccupied. Two principal forms of prehistoric stone terraces, built evidently for agricultural purposes, may be recognized in the Central American region, in addition to the narrow terraces of earth described in a previous section. There are (1) narrow, high terraces to hold drainage water and prevent erosion in the narrow valleys or on steep slopes of mountains and (2) broad, low terraces apparently leveled to keep rain water from running off rather than to apply irrigation.

Terraces of the first type are frequently met with in the heavily forested region in eastern Guatemala. Similar terraces are used at

the present time in the denuded mountains of northwestern Guatemala, between Santo Tomás and Jacaltenango. Terraces of the second type cover many square miles of unoccupied land in the semiarid plateau region of the Mexican State of Chiapas, between the Guatemalan boundary and Comitán, as well as between Comitán and Ocosingo. This terraced region is now covered partly by fire-swept grass lands and partly by scattered growths of pines and oaks, where the fires are less severe. In some localities to the east of Comitán the terraced lands are now used for agriculture, but the present occupation is obviously recent and has nothing to do with the building of the terraces. Indeed, it is difficult to convince the natives that the terraces are not natural features of the country.

The motive of the prehistoric people in building these broad terraces is not easy to understand unless they are considered as a method of dry farming. The walls are only a few feet high, though the area inclosed may be several acres in extent. Even without the terraces the land would often appear quite level, the slopes being extremely gentle. This makes it quite improbable that the terraces had the object of avoiding erosion, like the system of terracing followed in our Southeastern States. There is also no indication that they were intended to impound running water or that artificial irrigation was applied. The walls do not rise above the level of the land inclosed. The probability is that the complete leveling of the land was found useful to prevent the running off of any of the rather slight rainfall which comes to these semiarid districts. While the terraces are not high, the walls are often half a mile or more in length. The leveling of the land must have required vastly more labor than the building of the walls, but the work may have been done gradually if a regular practice of hoeing the earth toward the wall were followed.

EFFECTS OF AGRICULTURE ON FORMS OF EROSION.

That the ancient occupations of the humid mountain regions of eastern Guatemala by agricultural civilizations were very prolonged or were repeated in several prehistoric ages is indicated by the very severe erosion which this region has suffered. It is not likely that such deeply dissected contours would have been formed if the country had not been kept in a denuded condition for long periods of time.

There is practically no erosion at all on slopes covered with dense tropical forest. The soil is never loosened by frost, but is held in place by the matted roots of trees and thatched over with a compact layer of fallen leaves. On the steep slopes this covering sheds the rain so effectively that the subsoil often remains permanently dry and dusty.

The storage of water by the forest on these very steep slopes is largely limited to the wetting of the humus layer, which may be only a few inches thick. If the rains cease for only two or three weeks this slender supply of water is exhausted. The plants wilt and shrivel up as though suffering from a prolonged drought. Slopes too steep for any rain to penetrate are often occupied by desert types of vegetation, though immediately surrounded by the vegetation appropriate to the general humidity of the region.

The water of the torrents that gather from the forested slopes is still clean, even after heavy rains, or is made only slightly milky by the washings of the leaves. Only the erosion of the streams loosens any solid matter. After the forest has been cut and the dry brush has been burned off the loose surface soil is left fully exposed. More erosion can then take place in a single season than would be possible in many centuries of undisturbed forest growth.

DISTRIBUTION OF PINES AND OAKS DETERMINED BY CLEARING OF LAND.

The presence of open forests of pines and oaks is not determined by altitude. Pine forests occur under a wide variety of conditions and at all elevations. They extend from near sea level in eastern Guatemala through the dry and elevated interior to the tops of the highest volcanoes. The same may be said of the oaks, except that they do not appear to ascend as high as the pines. Wherever there are grassy, fire-ravaged tracts to be occupied, the pines and oaks appear to be able to establish themselves if sufficient time is allowed. About Lake Yzabal, in eastern Guatemala, there are pine forests very nearly at the level of the sea. In the Palenque district of southern Mexico the oaks descend in a similar manner. Oaks also grow close to the seashore in the district of Guanacaste, on the Pacific side of Costa Rica, as reported by Professor Pittier.

The natural habitats of the several species of pines and of the very numerous species of oaks of the Central American region are probably to be found on the dry exposed crags and summits of the mountains. These are the only places where these slow-growing types would be able to maintain footholds if they had to meet the competition of the tropical vegetation without the help of men and fires. It is this competition of the more luxuriant tropical types of vegetation that limits the spread of the pines and oaks in Central America, rather than any particular requirements of altitudes, temperatures, or other climatic conditions.

Ability to resist fire is the characteristic that enables the pines to establish themselves in open grass lands. Young pines with the growing bud surrounded by many green needles can survive fires that

kill seedlings of other plants. As the trees grow larger they are protected by a thickened bark which is a very poor conductor of heat and not readily combustible. Nevertheless, the survival of the pines depends on the chance of frequent fires which prevent the accumulation of grass in large quantities. With grass enough to burn, even large pines may be killed by fire and the pine forest driven back from areas it has already occupied. (See Pl. VIII.) In this way a species of wire-grass (Epicampes) is destroying forests of alders and pines on the upper slopes of the Vulcan de Agua in Guatemala. Before the access of fires this grass appears to have been confined to the crater and to the very dry upper slopes, where the pine trees are small and scattering. Now that the belts of humid forests lower down have been broken by clearings the grass has the assistance of fire and is destroying the trees with increasing rapidity.

There are no springs or streams on the upper slopes of the volcano, so that the grass is not pastured. Its long wiry stems and leaves accumulate until there are quantities of fuel sufficient to kill large trees and to drive back the forest for long distances at each conflagration. The lower the grass comes the more luxuriant its growth and the more destructive the next fire. This will continue as long as the grass is ungrazed or care is not taken to burn the grass every year in order to prevent the accumulation of dangerous quantities of fuel.

The roots of this grass are well protected from the fire by masses of the closely packed stems. These tufts remain wet while everything else is thoroughly dried. Except in rainy weather, no water can be obtained from the extremely coarse and loose volcanic ashes and rocks of which the upper parts of the mountain are composed. Weldenia and other native plants show striking adaptations for drought resistance. Even the alder has a remarkably thick, cheesy bark, which doubtless serves for the storage of additional supplies of water.

BURIED ROOTS SHOW FORMER EXTENSION OF PINES.

In eastern Guatemala the secondary character of supposedly primeval forests is shown by the fact that pine roots are often found in the ground in districts from which living pines have been completely driven out by the more luxuriant tropical types of vegetation. The Indians dig up the pitchy roots of the extinct pines and use them for torches. Such roots are found in the alluvial bottom lands of the Polochic Valley, near Panzós, almost at sea level, and also in the coffee district to the north of Senahu at altitudes of about 3,000 feet and upward. Both localities are distant several miles from any living forests of pine.

It is easy to understand that pines were more abundant in this region in former times than at present, because the native population

is known to have greatly decreased since the arrival of Europeans. Greater numbers of Indians would mean the clearing of a larger proportion of the land and larger opportunities for the spread of the pines.

DENUDED AREAS NOT NATURALLY UNSUITED TO FORESTS.

The districts now most deficient in forest covering and with the artificial desert conditions most intensified, are not those of broken contours and steep declivities, but are usually the level areas and gentle slopes—the places naturally well suited to support heavy forest growth. But they are also the locations which the Indians would always prefer as having the most fruitful soil and being the easiest to clear for planting. Wherever such level spots or gentle slopes in denuded districts are still fertile they are highly prized by the Indians, who even build walls around them to clear the land of stones and keep out the cattle. Many of these small, isolated, walled-in fields can be seen on the spurs of the hills about Salama. Agricultural motives may also account for much of the stone inclosures and terraces which cover the upper slopes of ruin-crowned mountains, like that above Rabinal in central Guatemala. Unlike the regular walls and courts on the summit of the mountain, these lower terraces have no regular plan and appear to have been built to level the earth and free it from stones. The Indians still plant these terraces with corn, though the lower slopes of the mountain are now barren, like much of the adjacent country.

FORESTS IN ROCKY AND PRECIPITOUS PLACES.

In no part of Central America do the natural conditions exclude the growth of trees. Localities too remote from water or too inaccessible, rocky, or precipitous to serve any agricultural purpose are invariably supplied with forest growth. In inhabited districts where there is a scarcity of lands suitable for corn planting, extremely rocky and precipitous places are cleared and burned over for the sake of the single crop of corn that can be grown from the little soil which has accumulated in the interstices of the rocks. The reforestation of such places takes place with extreme slowness, for although the vegetation does not consist of grass it becomes thoroughly dried every year and is likely to burn up, even without being cut. In some districts, as about Nenton in the Department of Huehuetenango, Guatemala, the Indians do not take the trouble to cut the brush, but simply send the fire through it and plant their corn among the dead poles, as already noted among the native systems of corn culture.

The fact that forests are still to be found in the most unfavorable places shows that the rainfall is sufficient for the growth of trees

throughout the Central American region. Differences of natural conditions can influence only the factor of time, but could not prevent an ultimate reforestation. How many centuries or millenniums would be required to reclothe with forests such deserts as these of the valley of Salama is a question in which many considerations of soils, drainage, temperature, and rainfall would enter, but it seems superfluous to doubt that the result would be finally attained, if there were no men to cut down the trees and kindle fires.

SUMMARY.

The distribution of grass lands and of open forests of pines and oaks in Central America does not depend primarily upon natural conditions, such as contours, elevations, soils, or rainfalls, but is chiefly determined by previous occupations of the land by agricultural natives. Pines and oaks represent stages of the process of reforestation; they descend even to sea level to occupy open country where the fires exclude other less hardy vegetation. The former existence of pines in regions now occupied by luxuriant tropical forest is often shown by the persistence of the pine roots in the ground.

The driest and most sterile localities, those too forbidding for human occupation, have retained their forest growth, scarcely excepting sheer precipices and exposures of bare rocks. The regions which are now treeless and barren or covered only with grass are those naturally well suited for the growth of forests, for the formation of fertile soil, and for human occupation. Indications of prehistoric agriculture are found in all the denuded areas, as well as in other regions now covered with forests.

Truly virgin forests seem not to exist in Central America. Relics of ancient agricultural occupations seem nowhere to be lacking, even in regions now entirely uninhabited, in dense forests as well as in open desert regions.

The abundance of rubber and other temporary types of trees and the absence of humus-inhabiting arthropods and forest palms enable regions of recent reforestation to be distinguished from forests of older growth.

Facts of several different kinds thus support the conclusion that the Central American region had a continuous forest covering before the advent of agricultural man. If human interference were withdrawn the normal growth of the vegetation would again cover the Central American region with dense and continuous forests.

Repeated clearing and burning of the woody vegetation for the planting of corn allows the land to become overgrown with coarse grasses. The burning over of the grass lands prevents the growth

of young trees, and may even drive back and destroy adjacent forest. As long as the burning continues the grasses remain, but with the cessation of fires the forest growth is renewed. Such processes of alternating denudations and reforestations have evidently continued in Central America for long periods of time.

It becomes evident that the simple operations of primitive agriculture, the mere cutting and burning of the natural vegetation, can induce desert conditions, even in naturally forested tropical regions. Though the effects of human activities may not be so direct or so obvious in temperate climates as in tropical countries, it is well to be aware of the fact that natural conditions can be profoundly altered by human agencies.

Apart from dangers of war or pestilence to which the ancient communities of Central America may have been exposed, their existence was definitely limited by methods of agriculture which denuded the country of its forests and destroyed the fertility of the soil. Civilization is at an end when an agricultural country ceases to be adapted to agriculture. To recognize these natural limitations of the primitive civilizations of Central America should make us more careful to appreciate and to correct the harmful tendencies of some of our own systems of agriculture.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. *Frontispiece.*—Denuded lands occupied by cactus deserts, near El Rancho, eastern Guatemala.

PLATE II. Denudation and erosion at Cahabón, in eastern Guatemala, a region naturally covered with heavy forests.

PLATE III. Mountain sides terraced for corn and wheat, district of Quezaltenango, western Guatemala.

PLATE IV. Denuded mountains in eastern Guatemala partially reforested with scattering pines; tropical vegetation in the deeper valleys.

PLATE V. Valley in open pine forest with advancing growth of tropical trees, Cahabón district, eastern Guatemala.

PLATE VI. Tropical growth in a reforested valley like that shown in Plate V; dense shade excludes the grass and puts an end to fires.

PLATE VII. Denuded, fire-swept slopes above the valley of Salama, Guatemala, reforested with scattering pines. The clouds are over the oak-forested mountains in the distance. A column of heated air rising from a denuded district can often be seen to absorb the clouds which drift over from a neighboring forested area.

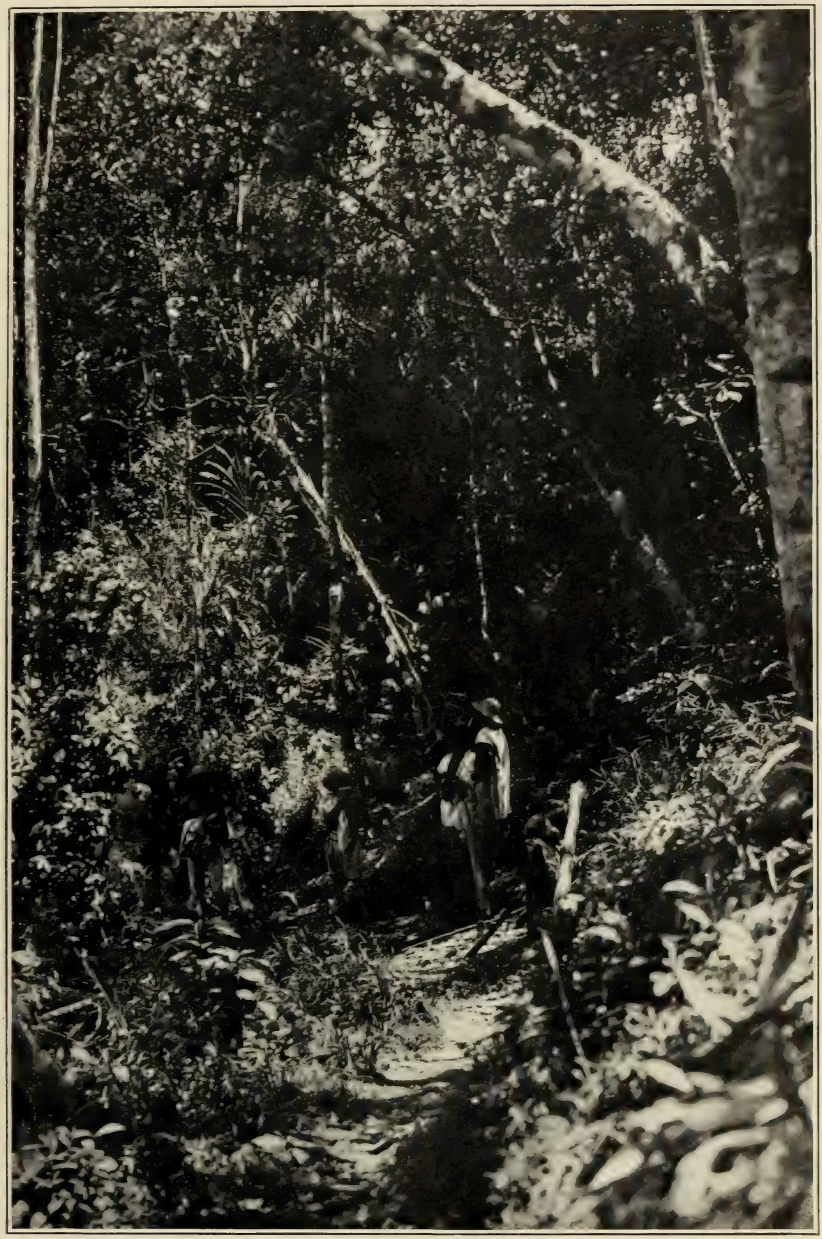
PLATE VIII. Fig. 1.—Pine forest and bunch-grass on the upper slopes of Vulcan de Agua, Guatemala. With grass enough to burn, even large pines may be killed by fire and the forests driven back from areas they have already reoccupied. Fig. 2.—Pine forest inside the rim of the crater of Vulcan de Agua, Guatemala.

DENUDATION AND EROSION AT CAHABÓN, EASTERN GUATEMALA, A REGION NATURALLY COVERED WITH HEAVY FORESTS.

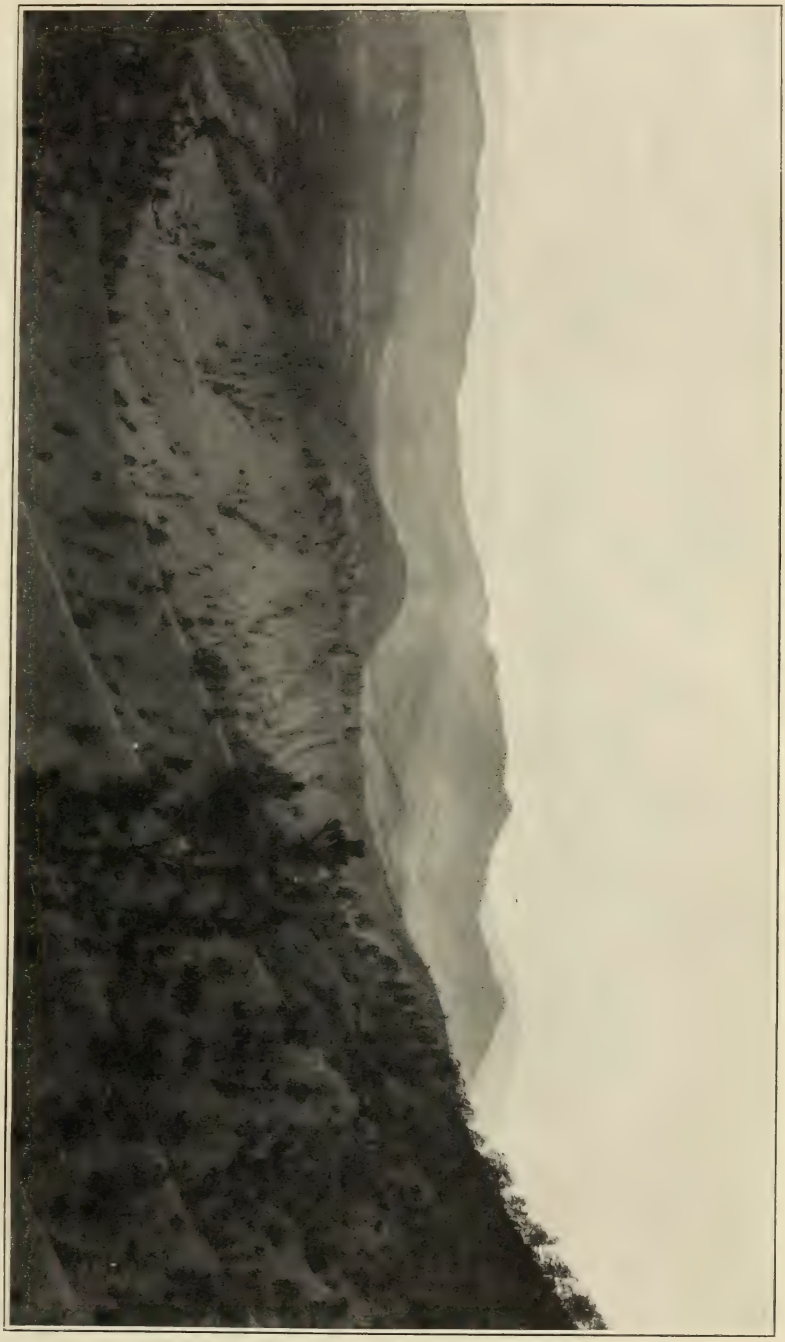
MOUNTAIN SIDES TERRACED FOR CORN AND WHEAT, DISTRICT OF QUEZALTENANGO, WESTERN GUATEMALA.

DENUDED MOUNTAINS IN EASTERN GUATEMALA PARTIALLY REFORESTED WITH SCATTERING PINES; TROPICAL VEGETATION IN THE DEEPER VALLEYS.

VALLEY IN OPEN PINE FOREST WITH ADVANCING GROWTH OF TROPICAL TREES, CAHABÓN DISTRICT, EASTERN GUATEMALA.



TROPICAL GROWTH IN A REFORESTED VALLEY LIKE THAT SHOWN IN PLATE V; DENSE SHADE EXCLUDES THE GRASS AND PUTS AN END TO FIRES.



DENUDED, FIRE-SWEPT SLOPES ABOVE THE VALLEY OF SALAMA, GUATEMALA, REFORESTED WITH SCATTERING PINES.

FIG. 1.—PINE FOREST AND BUNCH-GRASS ON THE UPPER SLOPES OF VULCAN DE AGUA, GUATEMALA.

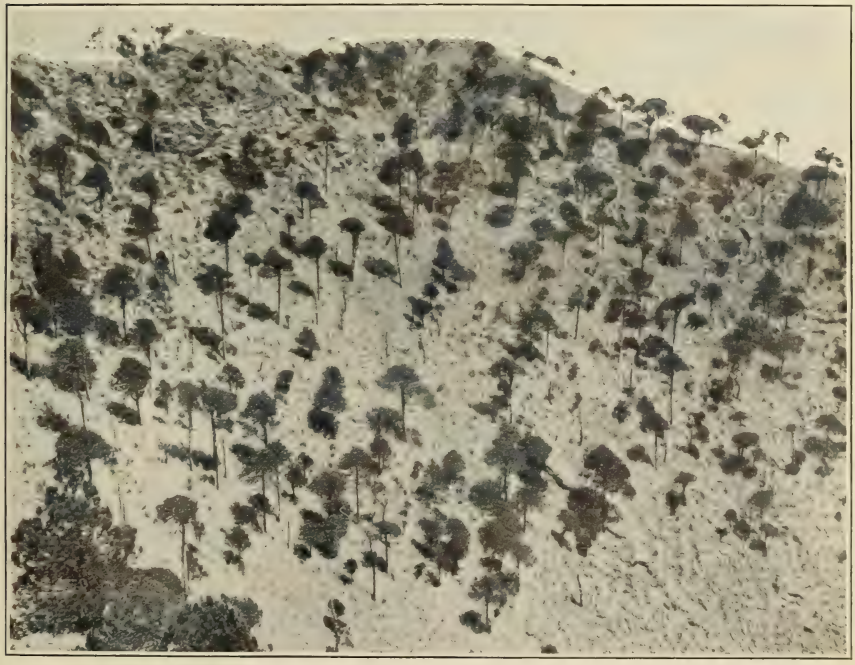


FIG. 2.—PINE FOREST INSIDE THE RIM OF THE CRATER OF VULCAN DE AGUA, GUATEMALA.

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